DEVELOPMENT OF LIGHT WEIGHT PROPELLER BRACKET

by

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ABSTRACT

The purpose of this thesis is to design, analyze and fabricate the light weight propeller bracket which is contributing to the stability of the Merlin light aircraft because the existing design are overweight. This problem cause the aircraft not stable during flight. This research is focus on the mass of CAM100 that are overweight due to the design of propeller bracket. The new design is made by using topology optimization from ANSYS software. The optimized structure is then converted into the truss element. Truss structures and space frame have been preferred solution to the problem of maximizing structural efficiency as they allow for very large increase in the flexural rigidity and load carrying capacity plus it has strength to weight ratio. The new design method such as truss element method and composite structure are used as new design for the structure which have weight reduction. The structure then is analyzed by using Finite element method and it is compared with analytical method to ensure there is no failure during engine operation. The best design then fabricated for truss element structure and composite material structure. The final weight reduction is taken to compare which has higher weight reduction The result show that new design has weight reduction which give aircraft more stability.

PEMBINAAN PROPELLER BRAKET YANG RINGAN

ABSTRAK

Tujuan tesis ini adalah untuk merekabentuk, menganalisis dan membuat pendakap kipas ringan yang menyumbang kepada kestabilan pesawat ringan Merlin kerana reka bentuk yang sedia ada adalah lebih berat. Masalah ini menyebabkan pesawat tidak stabil semasa penerbangan. Penyelidikan ini memberi tumpuan kepada jisim CAM100 yang berlebihan berat badan akibat reka bentuk pendakap kipas. Reka bentuk baru dibuat dengan menggunakan pengoptimuman topologi dari perisian ANSYS. Struktur yang dioptimumkan kemudiannya diubah menjadi unsur kekuda. Struktur dan kerangka ruang utama telah menjadi penyelesaian yang lebih disukai untuk masalah memaksimumkan kecekapan struktur kerana ia membolehkan peningkatan yang sangat besar dalam lenturan ketegaran dan kapasiti beban beban ditambah nisbah kekuatan kepada berat. Kaedah reka bentuk baru seperti kaedah elemen kekuda dan struktur komposit digunakan sebagai reka bentuk baru untuk struktur yang mempunyai pengurangan berat. Struktur kemudiannya menganalisis dengan menggunakan kaedah elemen Finite dan dibandingkan dengan kaedah analisis. Reka bentuk terbaik kemudian dibuat untuk kekuda struktur unsur dan struktur bahan komposit. Pengurangan berat badan terakhir dibawa ke campare yang mempunyai pengurangan berat badan yang lebih tinggi Hasilnya menunjukkan bahawa reka bentuk baru mempunyai pengurangan berat badan yang memberikan kestabilan pesawat lebih.

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Finally, greatest appreciation to all relatives, friends, seniors and others who in one way or another shared their encouragement and support, either morally, financially and physically.

ENDORSEMENT

I, Mohamad Rukaini Bin Mazlan hereby declare that I have checked and revised the whole draft of dissertation as required by my supervisor.

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(Signature of Student)

Date:

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(Signature of Supervisor)

Name:
Date:

ENDORSEMENT

I, Mohamad Rukaini Bin Mazlan hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

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Date:

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(Signature of Examiner)

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Date:

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LIST OF ABBREVIATIONS

CG	Centre Gravity
FEA	Finite element analysis
FEM	Finite element method
W	Width
FS	Safety factor
CP	Centre pressure

NOMENCLATURE

U_d	:	Energy density
A	:	Cross sectional area
E	:	Young Modulus
b	:	Width
k	:	Buckling coefficient
m	:	Mass
t	:	Thickness
v	:	Poisson’s ratio
F	:	Force
M	:	Moment
W	:	Weight
σ	:	Stress
S_{al}	:	Allowable strength

CHAPTER 1 INTRODUCTION

1.0 Project Background

This research is focus on the mass of CAM100 propulsion system that face overweight problem due to the design of propeller bracket that are too bulky. This problem will affect the static and dynamic stability of the aircraft. The bulky design will lead to the overweight of aircraft that will affect the static and dynamic stability of aircraft.

Truss structures and space frame have been preferred solution to the problem of maximizing structural efficiency as they allow for very large increase in the flexural rigidity and load carrying capacity. The approach of this research and development is to solve the design problem of the propeller bracket. The new design method such as truss element method will be used as new design for the structure. Another approach is by using composite material as replacement of existing structure. Composite material is combination of two materials in a single structure. The advantage of composite is it has lower weight and stronger structure.

1.1 Problem Statement

The personal aircraft has a design problem. The nose of aircraft is heavier than the tail. This problem will cause the aircraft need more speed to gain altitude. The aircraft faces problem during landing. The main problem that cause heavy nose is the structure of propeller bracket from CAM100 engine that are bulky and heavy. Therefore, the approach taken in this research is by developing new structure of propeller bracket.

1.2 Objective of project

The objectives of this project are as follows.

1. To design new structure of propeller bracket that will have lower weight by using truss element and composite structure
2. To analyse the structure of propeller bracket that from truss element and composite structure
3. To compare the structure of propeller bracket between existing structure, truss element and composite structure and to fabricate the optimum design structure of propeller bracket

1.3 Thesis Layout

This thesis consists 5 chapters. Chapter 1 gives a project background related to the CAM100 engine and the propeller bracket. The design of the actual propeller bracket is discussed in this section. Then, the general concept about a light weight propeller bracket is also introduced in this chapter where it will be the main idea in developing this project. Finally, the objectives of the project are defined.

Chapter 2 reviews all literatures related to this work. This section involves research in journal that had been formerly made by other which are related directly to the project that will be developed. The purpose of this chapter is to attain genuine knowledge and information corresponding to the project field. In this section, the literature in designing the light weight propeller bracket and any structure related to it had been analyze and interpreted.

In Chapter 3, the method and process used in this project had been explained in detail. All systematic, theoretical analysis and practical process are described in the methodology. This chapter consist 4 parts which related in developing this project from its first design to a complete fabrication process.

Chapter 4 is concerning about the result and the discussion of the project. This chapter present the finding and outcomes of research and reasons for a particular result obtain through practical and analytical analysis justified in the methodology. In this section the comparison between the development project with the theoretical and some result had been verified in order to have a valid result.

Finally, Chapter 5 is involving the conclusion and recommendation where logical deduction based on result obtain in the chapter 4. The comprehensive summary about the project are included which generally state the overall process in developing this project. At the end of the thesis, there will be some recommendation and future work stated to improve the project development.

CHAPTER 2 LITERATURE REVIEW

2.1 General Overview of Aircraft

The aircraft used as the design and development of lightweight propeller bracket is Blue yonder Merlin Series as shown in figure 2.1. This type of aircraft was designed in 1986 and has first flight in 1987. The design is still impoving year by year untill now. It is a personal aircraft with high wing monoplane with taildragger undercarriage. It is ultra-light aircraft with aluminium and foam rib construction as its structure. Merlin Series has almost same flight performance as the normal personal aircraft. The aircraft performance and general characteristic are as follows:

Table 2.1 Aircraft performance

Performance	**Unit**
Maximum speed	104 kn; 193 km/h (120 mph)
Cruise speed	96 kn; 177 km/h (110 mph)
Rate of climb	1,400 ft/min (7.1 m/s)
Wing Loading	8.75 lb/sq ft (42.7 kg/m^2)

Table 2.2 General characteristic of aircraft

General characteristic	Unit
Length	23 ft 0 in (7.01 m)
Wingspan	35 ft 6 in (10.82 m)
Height	7 ft 0 in (2.13 m)
Wing area	235 sq ft (21.8 m^2)
Empty weight	700 lb (318 kg)
Max takeoff weight	1,400 lb (635 kg)

With its own general characteristic, merlin aircraft normally are used for flight school and others simple used. It has variation design and it can fix to many type of engines. This research is focus on the cam100 engine which has design problem.

Figure 2.1 Merlin Aircraft

. 2.1.1 Firewall Forward Cam100 Engine

The engine model attached in this Aircraft is Firewall Forward Cam100 Engine as shown in Figure 2.2. The Firewall Forward Cam100 Engine has four-cylinder and four-stroke liquid cooled piston aircraft engine. The power output for the engine is 100 horsepower with 74.4kW at the propeller flange. The direction of rotation of the engine is clockwise direction. The engine block is one-piece aluminum with re-borable cast iron liners. The reduction system for the engine to the propeller is by using HTD Cog Belt and the reduction ration is from 6000rpm to 2500rpm speed.. Propeller bracket hold the propeller of the aircraft and connect between propeller and engine. The belt transmits the rotation engine with maximum 6000rpm to 2500 rpm for the propeller rotation. The main force propeller bracket structure need to sustain is compression force with 150 hp at the propeller flange. The structure face the compression force because of the rotation pulley that rotate and create compression force between engine shaft and propeller shaft.

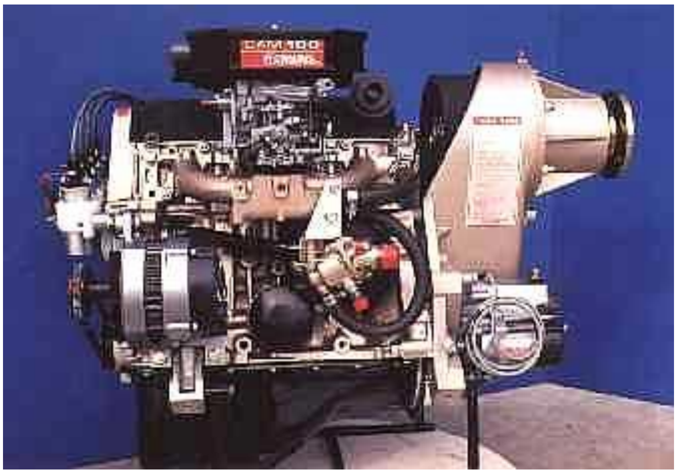


Figure 2.2 CAM100 Engine

The others specification of Cam100 engine are list as belows:

Table 2.3 Engine properties

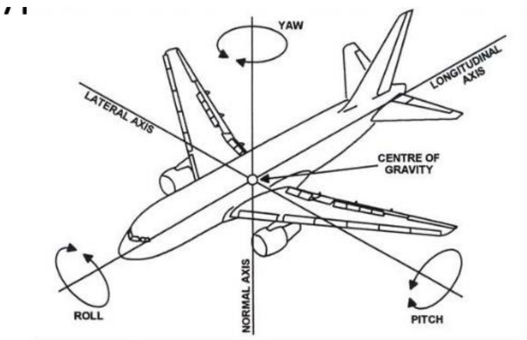
Compression ratio	9:6:1
Camshaft	Cast alloy, aluminum, cross flow design
Displacement	1488cc(90.7 cubic inches)
Cooling	Water-glycol mixture. Water pump driven by camshaft belt
Dimension	Height-25in,Length-32in,Widh-19in
Reduction ratio	2:4:1

From the table 2.3 the dimension stated can be considered for the work progress to detach the propeller bracket from the engine. The weight for propulsion system is 103.2kg. The weight included the propeller bracket. At the end of this project the weight of the propeller system should lower than the initial weight of the propeller system. The others factors should be included during engine operation are the increase in temperature and vibration during flight. The temperature increase when the belt rotates and the friction between belt and pulley produce heat. The engine vibrates at certain frequency and the existing structure of propeller bracket able to withstand the frequency of vibration . For the increase in temperature, the engine has the cooling system which help decrease the temperature during engine operation.

The propeller bracket is made of aluminum and manufactured by using sand casting method. The main structure of propeller bracket is cast aluminum structure. But this design of propeller bracket is too bulky. This bulky design causes the engine to overweight. For the new design the structure able to withstand compression force vibration and increase in temperature. The new design should have able have lower weight than existing structure.

2.2 Aircraft stability

All aircraft has its own stability. Stability is the initial tendency of an aircraft to return to its original position when it is disturbed. Stability of aircraft will allow aircraft to maintain a stable flight condition. Stability considers the response of aircraft to perturbation in flight condition from some dynamic equilibrium, while control considers the response of the aircraft to control input. In reference(Caughey, 2011) . There is two type of stability which is static stability and dynamic stability. Static stability is the tendency of the aircraft response to a perturbation is towards a restoration of equilibrium. Dynamic stability is when the aircraft ultimately return to the initial equilibrium state after some infinitesimal perturbation. In static dynamic, if the response increase in angle of attack of the vehicle generates a pitching moment that reduces the angle of attack (statically stable). However, if the initial tendency to return toward equilibrium leads to an overshoot, it is possible to have an oscillatory divergence of continuously increasing amplitude, thus the vehicle can be statically stable and dynamically unstable(Caughey, 2011). There is three axis of aircraft motion which is Lateral, longitudinal and directional stability. The merlin Aircraft focus on longitudinal stability which include pitching motion. The center gravity of the fuse lage and Centre of lift will affect the longitudinal stability.



Stability	Axes	Motion about the Axis
Longitudinal	Lateral	Pitch
Lateral	Longitudinal	Roll
Directional	Normal	Yaw

Figure 2.3 Stability Aircraft

2.2.1 Centre of gravity

The maximum allowable weigh for aircraft is determined by design consideration. The weight of aircraft must be distributed to keep the Centre of gravity (CG) within the limit specified. Center of gravity is the point through which the force of gravity is said to act on a mass (Buharali, 2004)From the Aircraft Weight and Balance Handbook if the CG of aircraft is far forward as shown in Figure 2.4 , there will be lack of sufficient elevator authority. At low takeoff speeds, the elevator might not produce enough nose-up force to rotate and while landing there may not be enough elevator to flair the airplane.

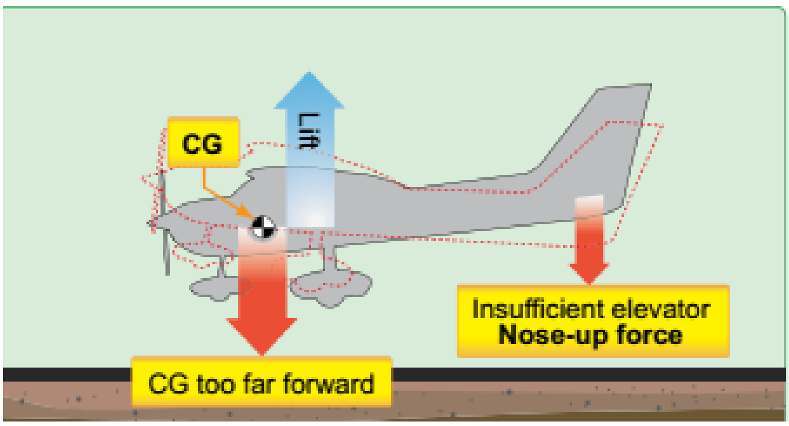


Figure 2.4 CG Foward Aircraft

If the CG is too backward and near the Centre of lift it is difficult to recover from a stall. The Centre of gravity should in between the range between CG and CL. The merlin personal aircraft have heavy nose problem. The downward force of tail or weight at tail need to be increase to maintain level of flight. This increase tail load has the effect as carrying additional weight. Increase weight result in low performance of aircraft. The weight of nose should be reduced in order to move the CG within the range to obtain stable aircraft.

2.3 Composite Material Structure

A Composite is , By definition , something made from two or more component that have different mechanical properties that combine together to produce new improved properties(Sanjay K. Mazumdar, 2002).From journal (Sanjay K. Mazumdar, 2002) A composite material consists of two phases. Primary phases and secondary phases as shown in Figure 2.5. Primary phases are the form of matrix within which the secondary phases are embedded. Example of primary phases is polymer, metals and ceramic. Secondary phases are referred as the imbedded phase or called the reinforcing agent. It serves to strengthen the composite such as fiber particle or flakes. But secondary phases are normally made of fiber.